SIA Software Company, Inc.

One Main Street • Whitinsville, MA 01588 USA • www.siasoft.com

SIA-Smaart® Pro Case Study #8
Polarity and Its Effect on a 2-Way Speaker Box

And Effects of Room Modes on Measurements in (Relatively) Small Rooms

Text by Sam Berkow, SIA, Measurements by Bill Hoy, EAW

For this case study, we measured a two-way loudspeaker, the EAW JF290z. We made measurements in a standard room, with dimensions of 31.6' length, by 26' width by 11.25' tall. The relatively small size of the room means that we were limited in making reflection-free measurements at low frequencies.

To start our measurement, we placed our microphone in front of the 2-way loudspeaker (directly on-axis) and in a vertical position between the two drivers. We then measured the delay through with both the high and low frequency drivers on. This allowed us to listen to the driver and make sure both elements were working (or at least making some reasonable sound).

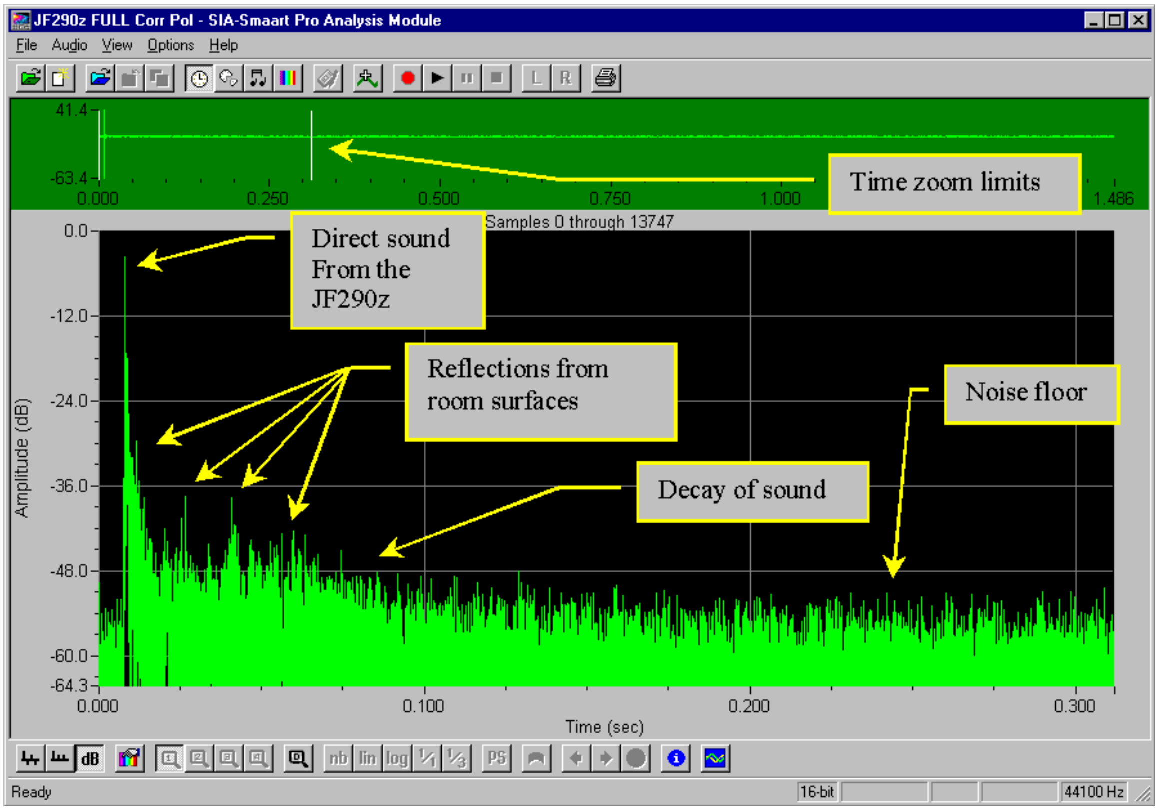

Figure #1: The impulse response measured by the Smaart's delay locator, displayed in Smaart's analysis module. Note the strong direct sound and the lower level of the visible reflections. A 64k FFT and 44.1kHz sampling rate with 3 averages were used in the delay locator.

We then made a measurement of the frequency response of the speakers, using Smaart's transfer function feature (again with both drivers on). The results of this second measurement are shown in *Figure #2* below.

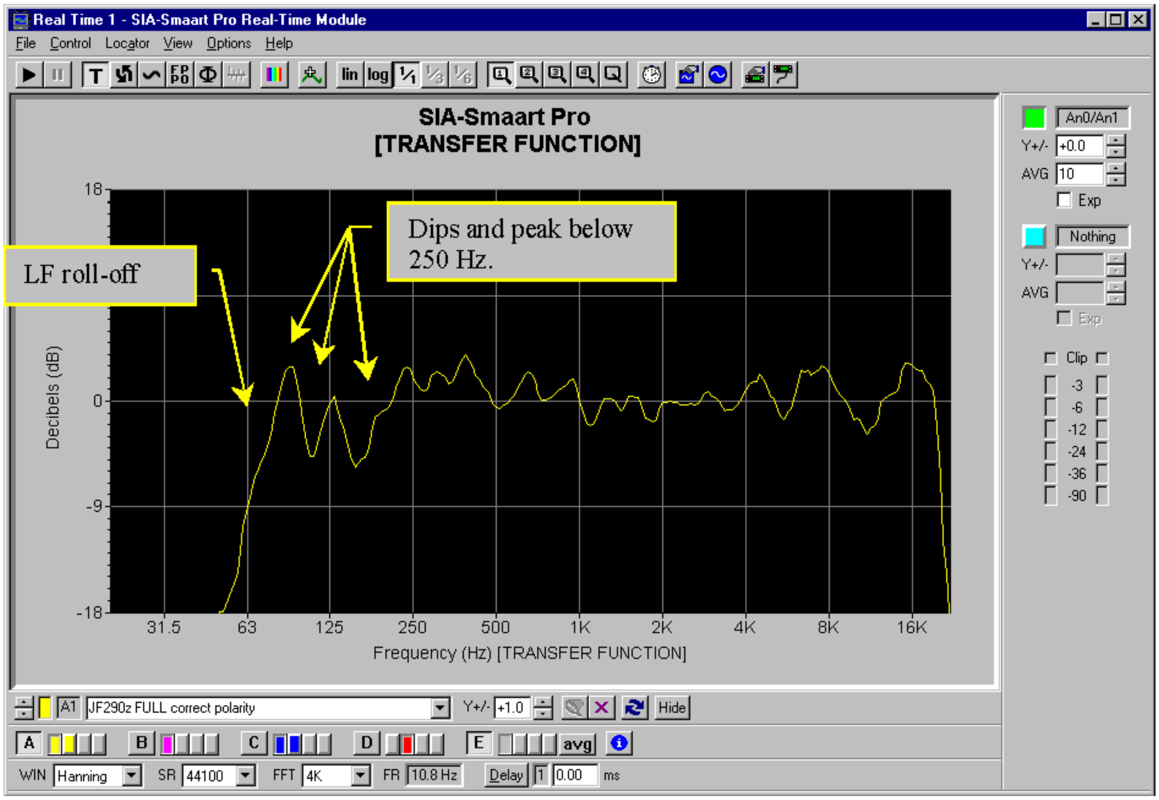

Figure #2: Frequency response of the EAW JF290z measured using a gently smoothed FPPO (fixed Point Per Octave) transfer function. Pink noise was used as a reference signal and 10 averages were included in the measurement. Notice that the speaker is extremely flat in the 250 to 16kHz frequency range. Below 250 Hz there seem to be two dips and one peak. The Low frequency roll-off of the loudspeaker is visible.

After saving the results of the second measurement as a Reference Trace, we repeated the measurement for each driver alone, looking at the response of both the low frequency and high frequency driver separately. The results of these two measurements are shown in *Figure #3* below.

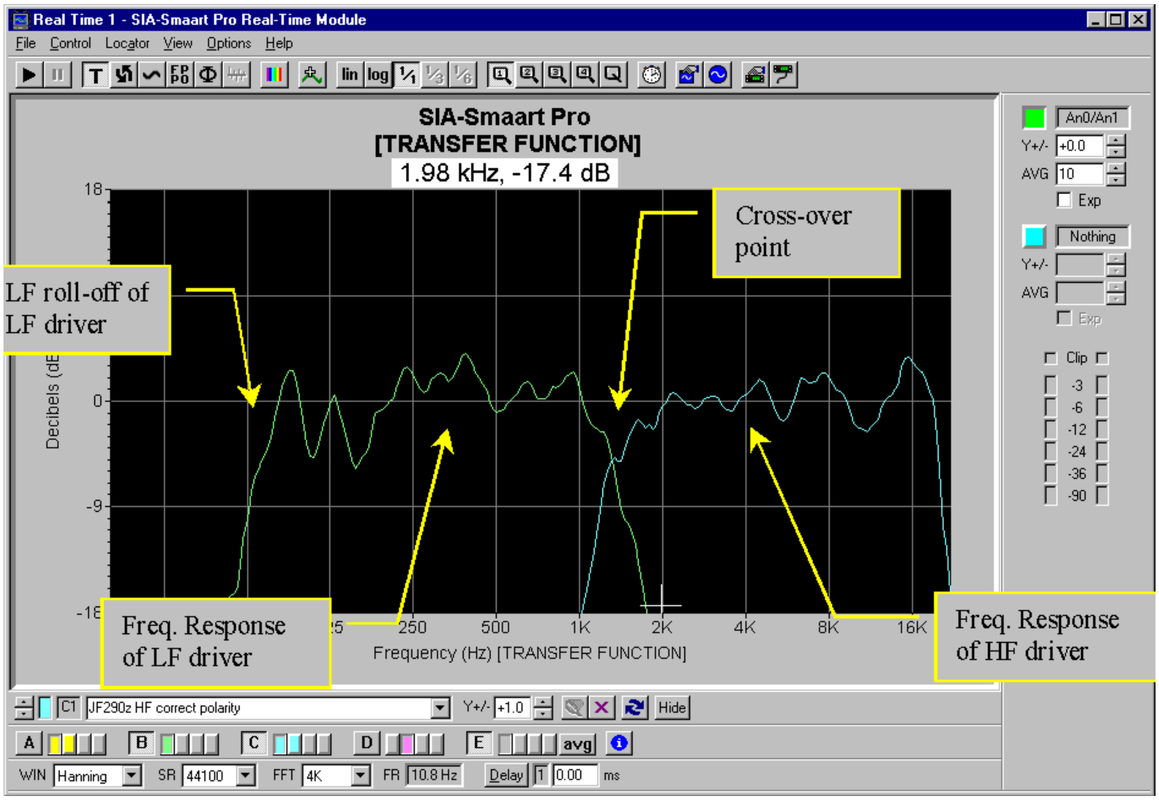

Figure #3: Frequency response of High Frequency (HF) and Low Frequency (LF) drivers in a JF290z. Note the roll-offs of the LF and HF drivers meet at ~-3B. Again the gently smoothed FPPO transfer function was used.

Figure #4 on the next page shows a comparison of the measurements in *Figures #2* and *#3* — the measurements of both drivers simultaneously *(Figure #2)* and each driver separately, as shown in *Figure #3 a*bove.

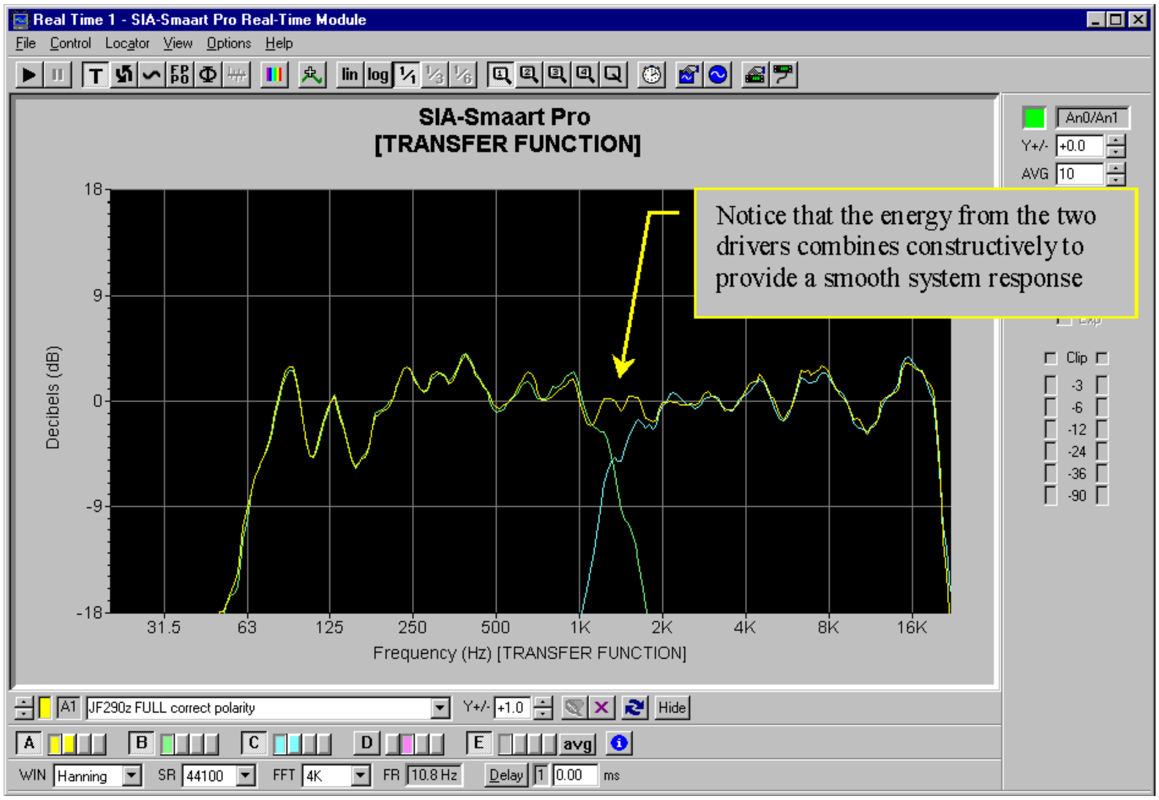

Figure #4: Frequency response of High Frequency (HF) and Low Frequency (LF) drivers in a JF290z measured separately (green and cyan traces) and together (yellow trace). Notice how the energy from the two drivers interacts constructively to provide a smooth system response (i.e. the response of both systems adds to ‘fill the hole” at crossover.

As a demonstration, we then flipped the polarity of the HF driver. Polarity is the way in which a driver moves, given a positive or negative signal. For example, if a driver moves outward given a positive going signal, the speaker is commonly said to have positive polarity. Interestingly, a change in polarity is the same as a 180 degree phase shift, as shown in *Figure #5* below.

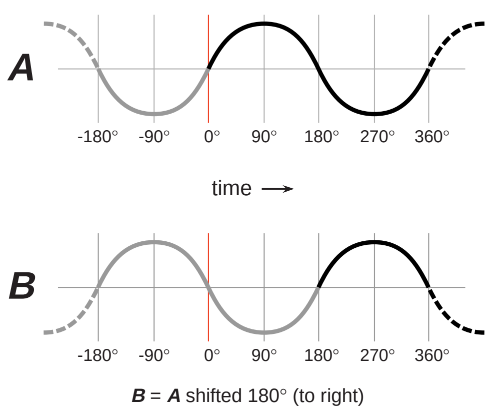

Figure 5: The figure above shows two sine waves. In part A of the figure a standard sine wave is shown. Notice that relative time is shown in degrees with each 90 degrees of shift equaling a quarter wavelength. In part B of the figure the sine wave has been shifted to the right by 180 degrees. Notice that the wave in part B is the same as the wave in part A only with opposite polarity (positive vs. negative).

Changing the polarity of a system can be done (both intentionally and accidentally) several ways. In this case we flipped the positive and negative terminals of the banana plug at the amplifier. To see the effect of this polarity flip we re-measured only the High frequency driver a 2nd time, and compared the result with our previous measurement:

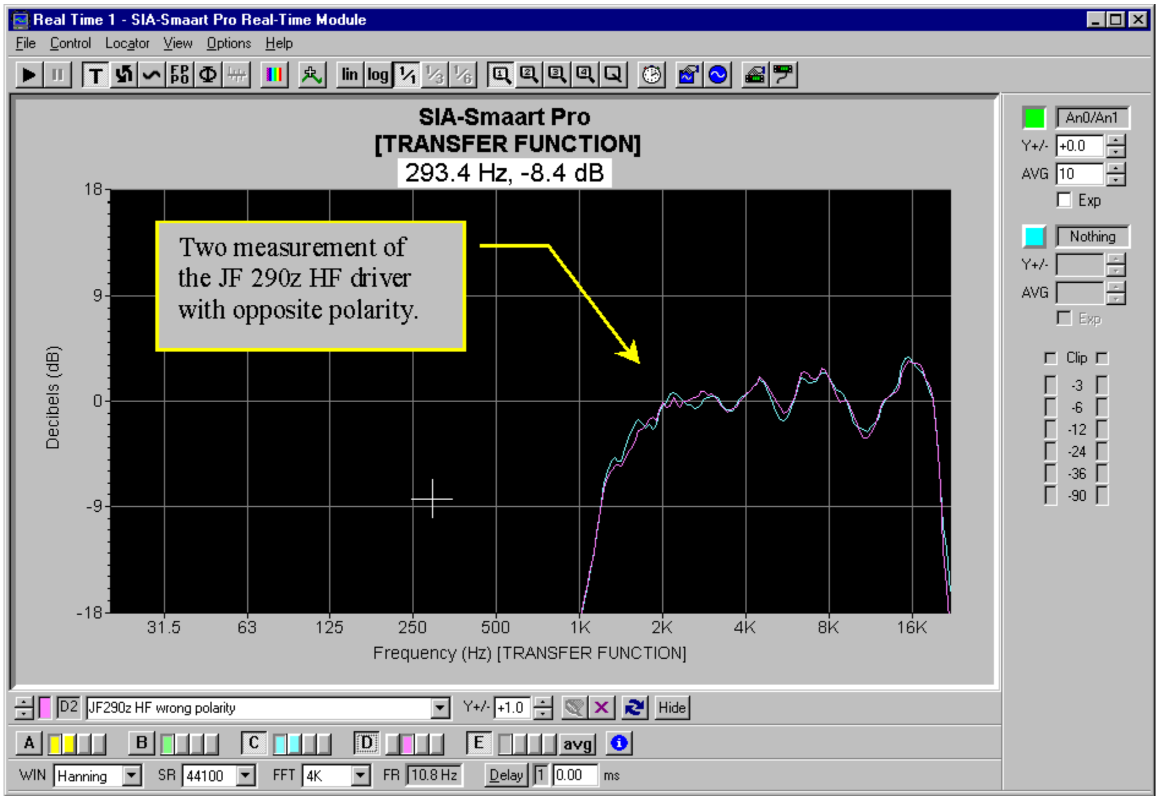

Figure #6: Two measurements of the HF driver alone. Notice that even though the polarity is positive in one measurement and negative in the other, the frequency response is almost identical. Any small differences can be reduced (or even eliminated) by increasing the number of averages for each measurement.

As shown in *Figure #6*, there is almost no difference in the measured frequency response of the High Frequency driver alone, with the polarity first positive and then negative. However, as shown in Figure #7 on the next page, the interaction between the HF and LF driver is affected greatly by the flip in polarity in the HF driver.

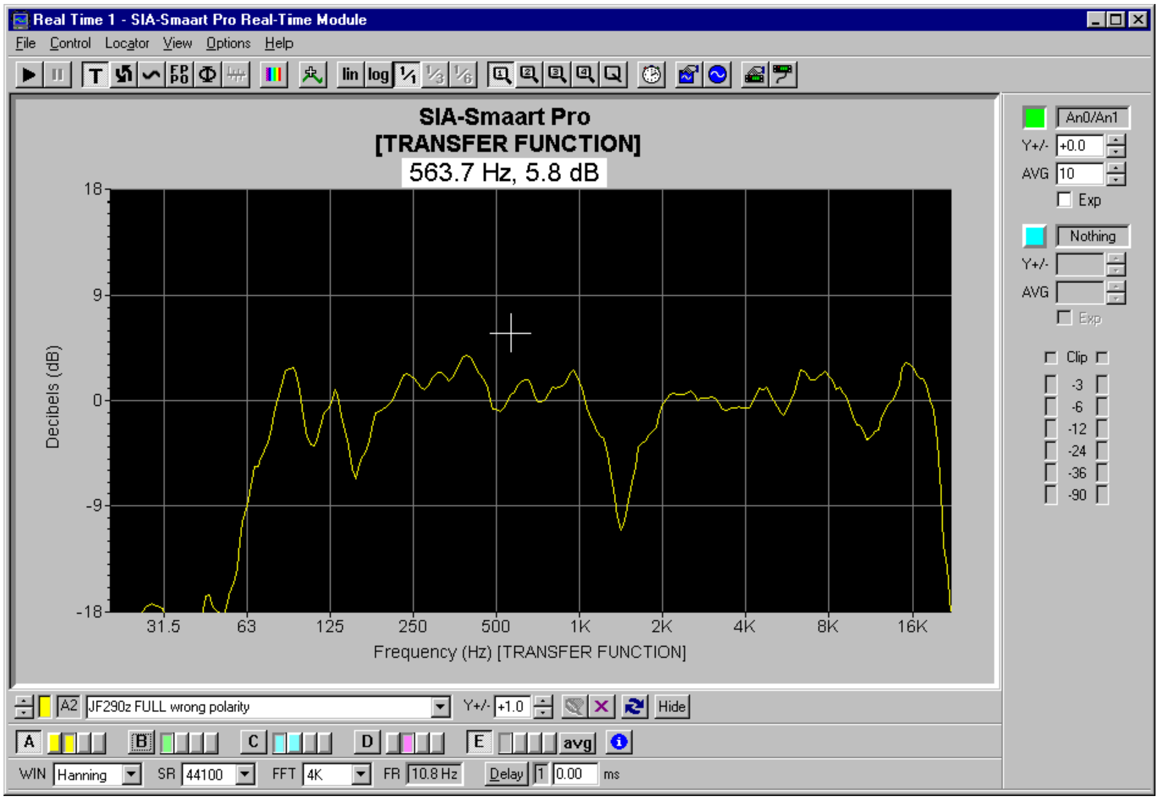

Figure #7: The frequency response of the loudspeaker with the polarity of the HF driver flipped (relative to the LF driver). Notice that the energy from the two drivers no longer adds constructively, creating a hole at the crossover frequency. This hole is clearly audible in vocals and other upper-mid range energy when listening to the speaker mis-wired.

Looking at the low frequency driver alone can offer some insight into the limitations of making measurements in relatively small rooms. Given that the room in which these measurements were made had dimensions of 31.6' length, by 26' width by 11.25' tall, we can use the simple room mode calculation to find the expected room modes.

A spread sheet that calculates room modes can be downloaded from the download section of the SIA web site www.siasoft.com. Entering the dimensions of our test room into this spreadsheet yields the table of predicted room modes shown in figure #8 below.

I	P from Length	Q from Width	R from Height
1	17.8	21.7	50.1
2	35.7	43.4	100.2
3	53.5	65.0	150.3
4	71.4	86.7	200.4
5	89.2	108.4	250.5
6	107.0	130.1	300.6
7	124.9	151.8	350.8
8	142.7	173.4	400.9

Figure #8 Room modes for a rectangular room measuring 31.6' (L) x 26' (W) x 11.25 (H).

Looking at the frequency response of the Low Frequency driver, we can see “peaks and valleys” the following frequencies:

peaks at: 89 Hz, and 128 Hz,

valleys at 106 Hz and 150 Hz.

Comparing the position (in frequency) of these peaks and valleys with the predicted room modes in figure #8 indicates that the peaks and valleys in the LF drivers frequency response fall on the room modes that appear in two columns of the predicted mode table. We have color coded the pairs of room modes in the predicted mode table that match the measured peaks or dips in the LF response. The reason for this interaction is that at low frequencies we are measuring not just the loudspeaker, but rather the interaction of the loudspeaker and the room.

So why does the room not affect the frequency response of the HF driver in the same way? As a rule of thumb, there is a frequency above which it is very hard to excite a single room mode. This frequency (know as the Schroeder frequency) is given as 3c/d where c is the speed of sound and d is a representative dimension of the room. In our case (using d = 11.25 ft.) we find that the modal transition frequency is ~ 298 Hz. Note that above this frequency our loudspeaker response does not seem to display strong peaks or valleys.

In summary, the polarity of drivers can greatly influence the response of a multi-driver system. When you see “holes” in the frequency response of a system) particularly at crossover, it may be a sign that you should check the polarity of the devices involved. At lower frequencies, peaks and valleys in a systems response can be caused by the interaction of the loudspeaker and the room. Using the rule of thumb 3c/d calculation it is easy to calculate the frequency range where modal response is expected. A simple spreadsheet can provide a list of expected modes, given the dimensions of a reasonably rectangular room.

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